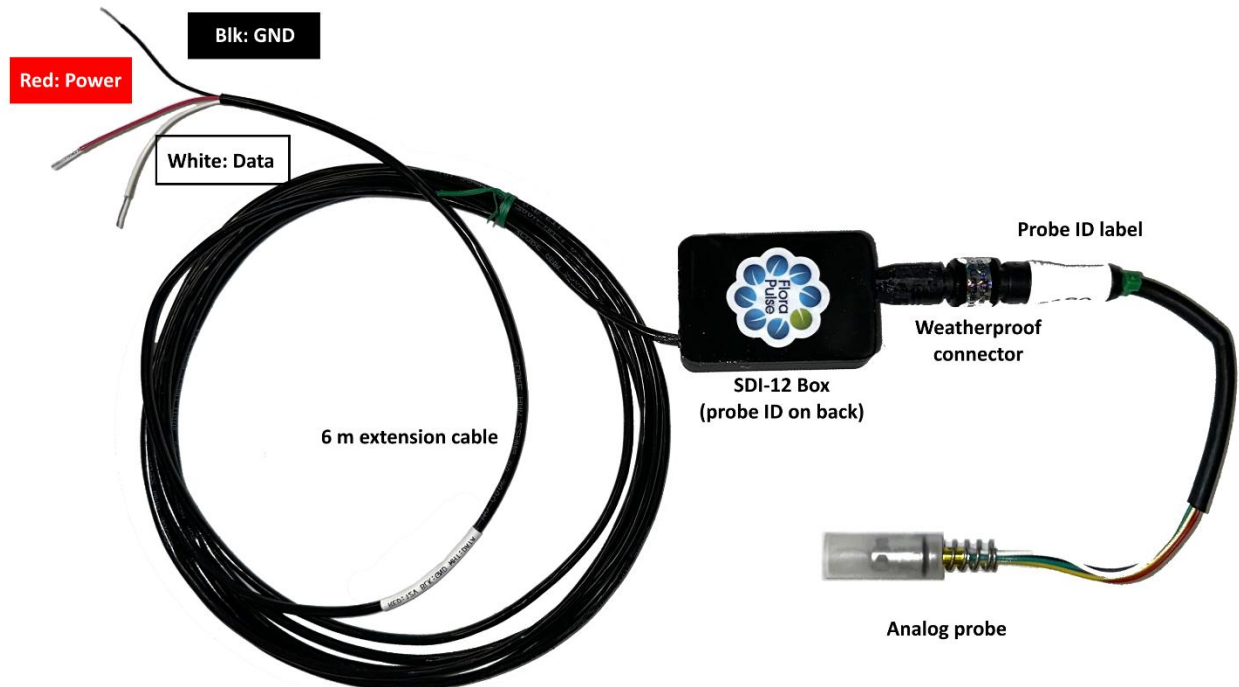


About:



The uTensiometer SDI-12 probe directly measures the tree water potential. It consists of one analog probe and one “SDI-12 converter box”. The analog probe is about 6” long and connects to the SDI-12 box through a twist-on waterproof connector. The SDI-12 box powers and reads the sensor, then transmits the information using the digital SDI-12 protocol. The SDI-12 box contains the calibration coefficients for the analog probe attached, but can be re-programmed using custom SDI-12 commands for a different probe (instructions below). The SDI-12 box is waterproof and comes with a 6m cable.

Connecting to a Logger:

The SDI-12 wiring is as follows: power wire (RED – connect to 3.6V to 16V), ground wire (BLACK – connect to GND), and data wire (WHITE – connect to DATA).

Communications:

The uTensiometer uses version 1.4 of the SDI-12 protocol. The sensor is addressable through the full range of the protocol and is set to the default address 0. Multiple SDI-12 boxes can be read through the same port if configured with different addresses.

The sensor provides stem water potential of a plant in units of bars as the first number output. The second number is a direct reading of the sensor in mV/V and the third number is the resistance of the probe thermometer in ohms. Communication commands are described below through an example probe with address ‘0’, later changed to address ‘4’.

SDI-12 Communication Examples:**Query the Address of a Sensor:**

```
sent:      ?!      (? !)  
response:  0      (address)
```

Sending “?!” to a sensor that is alone on the SDI-12 bus will query the address. The sensor responds with the default address of 0 as the current address.

Change the Address of the Sensor:

```
sent:      0A4!   (current_address A new_address !)  
response:  4      (address)
```

Sending “0A4!” instructs the sensor at address 0 to change its address to 4. The sensor responds with its new address of 4.

Identify the Sensor:

```
sent:      4I!                               (address I !)  
response:  414FLORAPLS0000011.1alpha1      (sensor_ID)
```

Sending “4I!” to the sensor’s new address will request the sensor to identify itself. The sensor responds with its current address (4), SDI-12 version (14), company name (FLORAPLS), sensor model number (000001), sensor version (1.1), and probe name (alpha1).

Start Measurement & Send Data:

```
sent:      4M!                               (address M !)  
response:  40023                             (address time(s) number_of_values)  
sent:      4D0!                             (address D0 !)  
response:  4-20.78-3.73+1269                (address+SWP+mV/V+resistance(ohm))
```

With checksum:

```
sent:      4MC!                               (address MC !)  
response:  40023                             (address time(s) number_of_values)  
sent:      4D0!                             (address D0 !)  
response:  4-20.78-3.73+1269.26GC'         (address+SWP+mV/V+resist checksum)
```

Sending “4M!” requests the sensor to begin taking a measurement. The sensor immediately responds with its address (4), 3 digits detailing in seconds (002) when the measurement will be ready, and 1 digit for the number of values (3).

Sending “4D0!” after 2 seconds causes the sensor to respond with its address (4), the stem water potential in Bars (-20.78), the direct reading of the sensor in mV/V (-3.73) and the resistance of the onboard thermometer in Ohms (1269.26).

Sending “4MC!” requests the sensor being taking a measurement and to calculate a checksum. The response is the same as with “4M!”. When “4D0!” is sent after 2 seconds, the response includes the previous data (address+SWP+mV/V+resistance), plus a 3-character checksum (GC’).

Get internal sensor temperature (not all probes have this!):

```

sent:      4M1!           (address M1 !)
response:  40022         (address time(s) number_of_values)
sent:      4D0!           (address D0 !)
response:  4-3.78+25.58  (address + SWP (bar) + Temperature (°C))
  
```

This feature is experimental and only available on some sensors. These specific sensors have an internal calibrated thermometer that gives the temperature of the sensor. This calibration is not accurate, but can give you a sense of the overall temperature fluctuations in your system. Use the command “AM1!” to get back the sensor SWP and temperature.

Custom Commands to Switch Out uTensiometers:

Each FloraPulse probe requires 5 calibration coefficients to calculate SWP from the output voltage and resistance. These coefficients are stored in the SDI12 box memory at the factory. Thus, every SDI12 box is paired with a specific sensor.

It is possible to switch the microtensiometer paired for a specific SDI12 box by uploading new calibration coefficients. The SDI12 boxes are thus reusable with different probes.

Equations:

Temperature (T, in °C) depends on the resistance (R, in ohms):

$$T = b_T + m_T R$$

Pressure (P, in bars) depends on the voltage (V, in mV/V) and calculated temperature (T, in °C):

$$P = m_P (V - (b_{PT} + m_{PT} T))$$

Probe coefficients:

Coefficient	Example value
m _P	-3.9
m _{PT}	-0.00103
b _{PT}	1.6709
m _T	0.50061
b _T	-568.2353

probe name	gamma3
------------	--------

List of Commands for each Value:

SDI-12 Command	Coefficient to set
XB	mp
XC	mPT
XD	bPT
XE	mT
XF	bT
XH	probe name

Each SDI-12 command sets a unique calibration value. The current address precedes the command. We recommend changing the calibrations with only a single SDI-12 box attached to the same port because the current address can be queried.

Changing mp, bpt, & probe name:

sent:	4XB-3.9!	(address XB new_mp_coefficient !)
response:	4-3.9	(address new_mp_coefficient)
sent:	4XD+1.6709!	(address XD new_bPT_coefficient !)
response:	4+1.6709	(address new_bPT_coefficient)
sent:	4XHgamma3!	(address XH new_probe_name !)
response:	4gamma3	(address new_probe_name)

After querying the address, sending “4XB-3.9!”, instructs the probe to memorize the mp value as -3.9. The probe responds with the address and the memorized value. The bpt and probe name are shown for a positive number and a word. All values will need to be updated to provide an accurate pressure measurement.

Typical sensor readings:

Here is an explanation of what sensor readings should look like.

- Stem water potential: +0.5 to -35 bar. Typical sensor readings should be between completely wet (~0 bar, maybe slightly positive due to noise) and the lowest water potential for your crop (down to -35 bars, lower values can damage the sensor). If the sensor reads very positive or negative values (i.e. +30 bars or -125 bars), then either (1) the sensor calibrations are incorrect, or (2) the sensor is broken and needs replacement. Sensor calibrations will always be incorrect if a sensor is attached to an incorrect SDI12 converter box – each box contains calibration factors for 1 specific sensor (indicated by the sticker on the box). When the sensors are placed in water, the reading should be close to zero SWP, and the voltage should be stable (fluctuating very little).
- Voltage: -31.25 mV to +31.25 mV. This is the range of the ADC. If the probe reading is stuck at either end (± 31.25 mV), this likely means the probe broke and needs to be replaced.

- Resistance: Some of our sensors include an internal thermometer, used mainly during manufacture. The thermometer is uncalibrated and inaccurate, but helps us test sensor function. Thermometer resistance is usually around 1,000 – 3,000 Ω . If the sensor lacks this thermometer, the interface will indicate -9,999 Ω . **Many sensors do not have this thermometer and this is completely normal. Thermometer resistance is unnecessary for normal sensor readings.**

Tips for reading (and troubleshooting) SDI12 sensors in the field reliably:

- **Use only FloraPulse sensors on the same SDI12 port.** Mixing different sensor types can cause crosstalk and communication interference.
- **If you must read FloraPulse and third-party sensors in the same SDI-12 channel, give FloraPulse sensors the lowest SDI12 addresses (0, 1, 2...).** This configuration minimizes communication conflicts with third party sensors.
- **Add 1-2 second delays between commands.** Insufficient delays between sending measure and read commands can prevent the logger from receiving complete responses. Try adding a 1-2 second delay between SDI12 commands (read and measure) if necessary.
- **Read sensors at most once per minute.** Trying to read the SDI12 box too frequently will cause communications to fail and you will get 'NaN' as a response.
- **Take measurements every 5 minutes.** This frequency ensures sufficient data collection even if some readings are missed due to communication issues. You want to have data at least every 20 minutes even if some measurements fail.
- **Save the raw data and do not average measurements.** The SDI12 protocol will sometimes fail to send data, and thus you may get NaN for some percentage of the readings. This is normally not a problem, since you can ignore the NaNs. But if your logger tries to average multiple readings, then as little as 1 NaN will cause your averaged reading to be NaN, effectively deleting all data for that period.
- **Ignore a small number of NaNs in your dataset.** Occasional communication failures are normal with the SDI12 protocol and won't affect overall data quality.

Specifications:

Wiring diagram

- Power: RED
- Ground: BLACK
- Data: WHITE

Electrical specifications:

- Power input: 3.6 V to 16 V
- Current drain: 0.65mA (sleep), 12mA (measurement)
- Measurement duration: 200 mS (typical)

Measurement specifications:

- Water potential
 - Resolution: 0.1 bar



uTensiometer SDI-12 Probe Manual

- Accuracy: $\pm 5\%$ of reading

Physical specifications:

- Probe length: 6"
- Cable length: 5 m
 - Extended cable lengths are available. Per SDI12 specifications, the maximum cable length is 60 meters.
- Connector type: IP67 waterproof

Sample datalogger programs:

You can download example programs to read FloraPulse analog and SDI12 sensors with Campbell Scientific dataloggers at [this link](#).